Vertical PIN GeSn light-emitting diodes on Silicon with 2.5 µm emission at room temperature

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Complementary metal-oxide-semiconductor (CMOS) technologies and scalable photonic integrated circuits (PICs) depend on monolithic infrared (IR) solid-state light sources grown on silicon. This monolithic integration is essential for low-cost, small infrared sensing and imaging systems [1]. In chemical plants, long-wavelength emitters like light-emitting diodes (LEDs) are utilized for air monitoring and spectroscopic identification of essential gases. III-V compound semiconductors are the predominant material used in commercially available LEDs at the 2-5 µm wavelength range; GaInAsSb/AlGaAsSb is the most widely used alloys [1,2]. However, because of material restrictions, these devices have an intrinsic emission gap in the 2.35–2.6 µm region. Additionally, in continuous wave mode as opposed to pulse mode, LEDs emitting at longer wavelengths show noticeably reduced output power [3]. Despite developments, III-V LEDs are still difficult to integrate into large-scale applications due to the high cost of their materials and the fact that their direct growth on silicon is frequently linked to device performance loss.

Group IV GeSn semiconductors have been investigated as a workaround for these issues. Due to their epitaxial growth atop silicon, these semiconductors may take advantage of proven, scalable production processes [4]. Furthermore, the bandgap may be tuned over the whole infrared wavelength range by varying the strain and Sn concentration. Although reports have indicated that GeSn LEDs can function in both DC and AC modes, no GeSn LED has been created to bridge the 2.35–2.6 µm emission gap of e-SWIR III–V LEDs [3,5]. DC-driven infrared LEDs emit light continuously, making them perfect for imaging and portable infrared systems that run on DC batteries. In contrast, AC-driven LEDs emit light in the form of quasi-continuous waves or pulses and lessen device heating by dissipating less thermal power. This work will present a demonstration of an all-GeSn vertical PIN LED with an emission peak in the 2.45–2.58 µm band as shown in Fig. 1. The realized GeSn LEDs function with DC bias at a comparatively modest injection current. The material growth and characterization will be presented to clarify the fundamental characteristics of the PIN heterostructure, such as lattice strain and Sn content, followed by the device performance. Furthermore, the band alignment of the developed GeSn stack will be estimated and the electrical structure of the resulting double heterostructure will be assessed using an eight-band k·p model. Subsequently, the electrical and optical measurements will be presented to examine the emission wavelength, emission power profile, bandwidth, and LED operation under DC- and AC-driven operation modes.

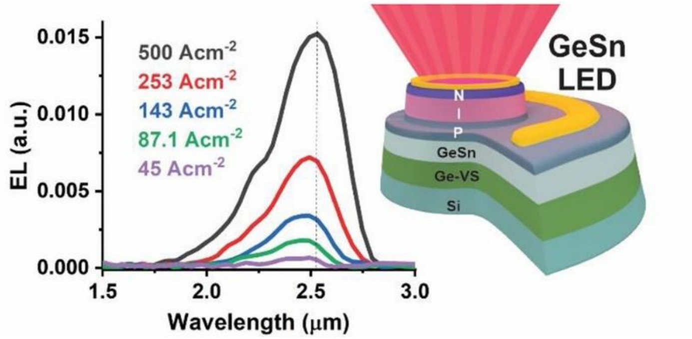

Fig. 1. Electroluminescence spectra of GeSn LEDs (left) and schematic of the PIN vertical LED (right)

References

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